

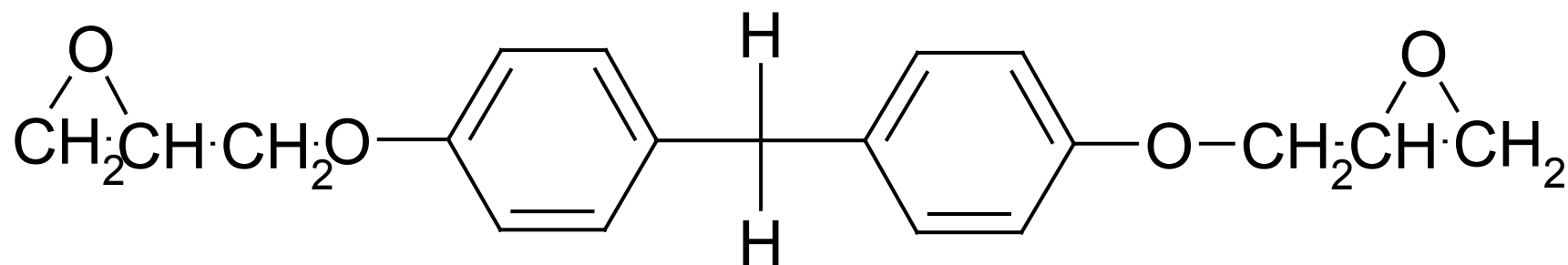
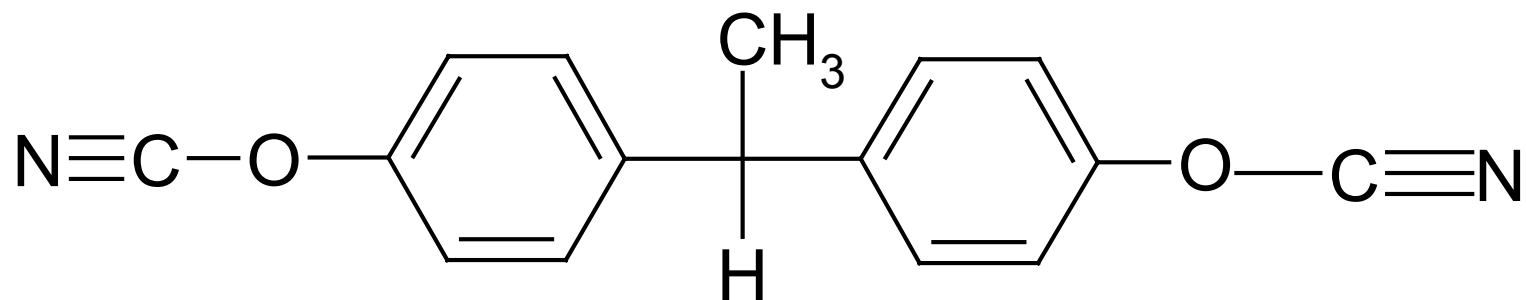
The chemistry and technology of epoxy and cyanate ester resins in comparison

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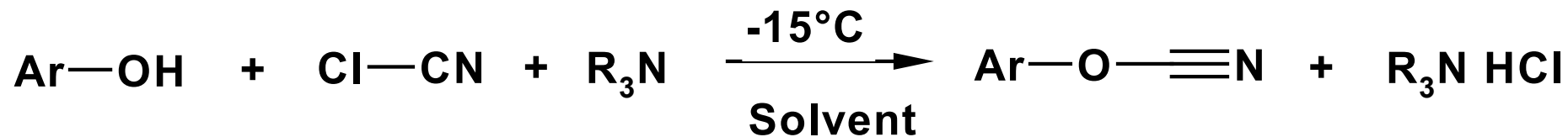
Outline

- Chemical structures
- Preparation of monomers
- Reactions
- Polymerization; role of the catalyst
- Physical properties of monomers
- Processing: Viscosity, Potlife, Curing Temperature/Time
- Safety considerations
- Typical applications
- Commercial status for AroCy[®] L-10

Chemical Structures



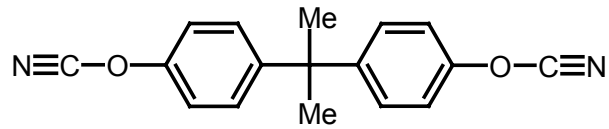
Preparation of Cyanate Esters



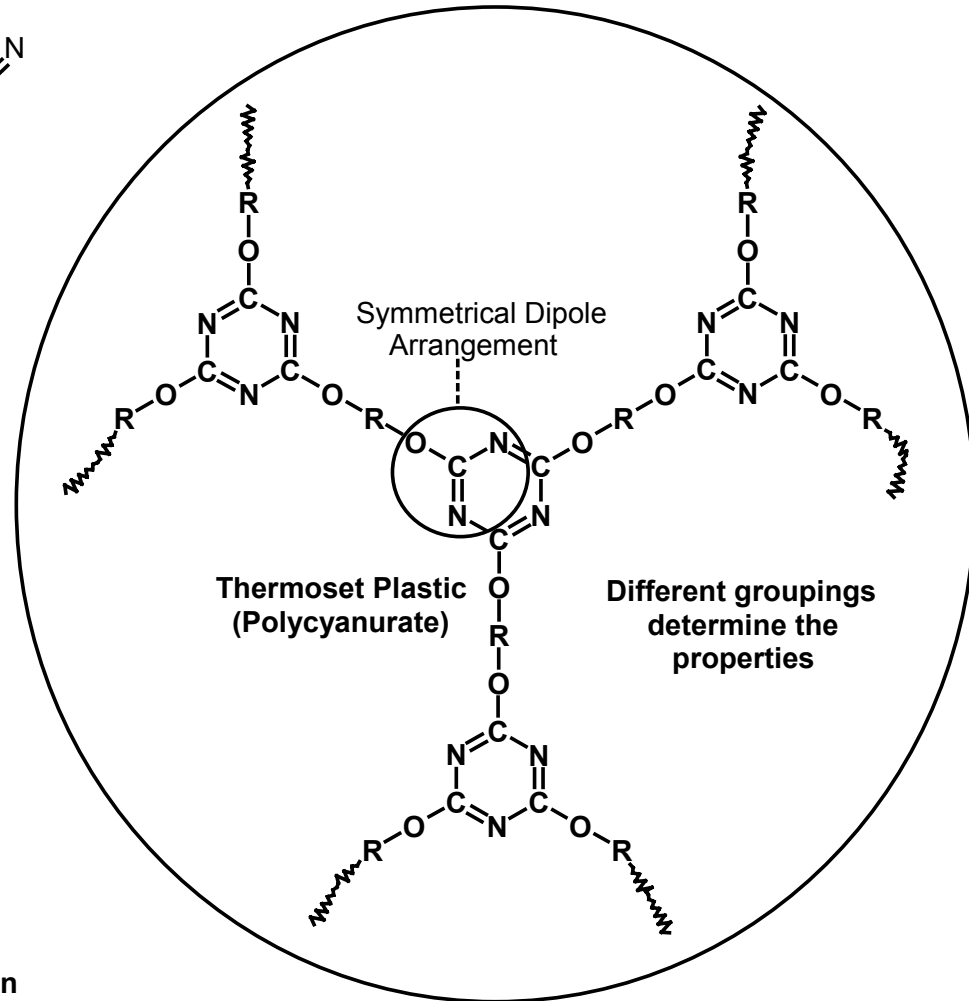
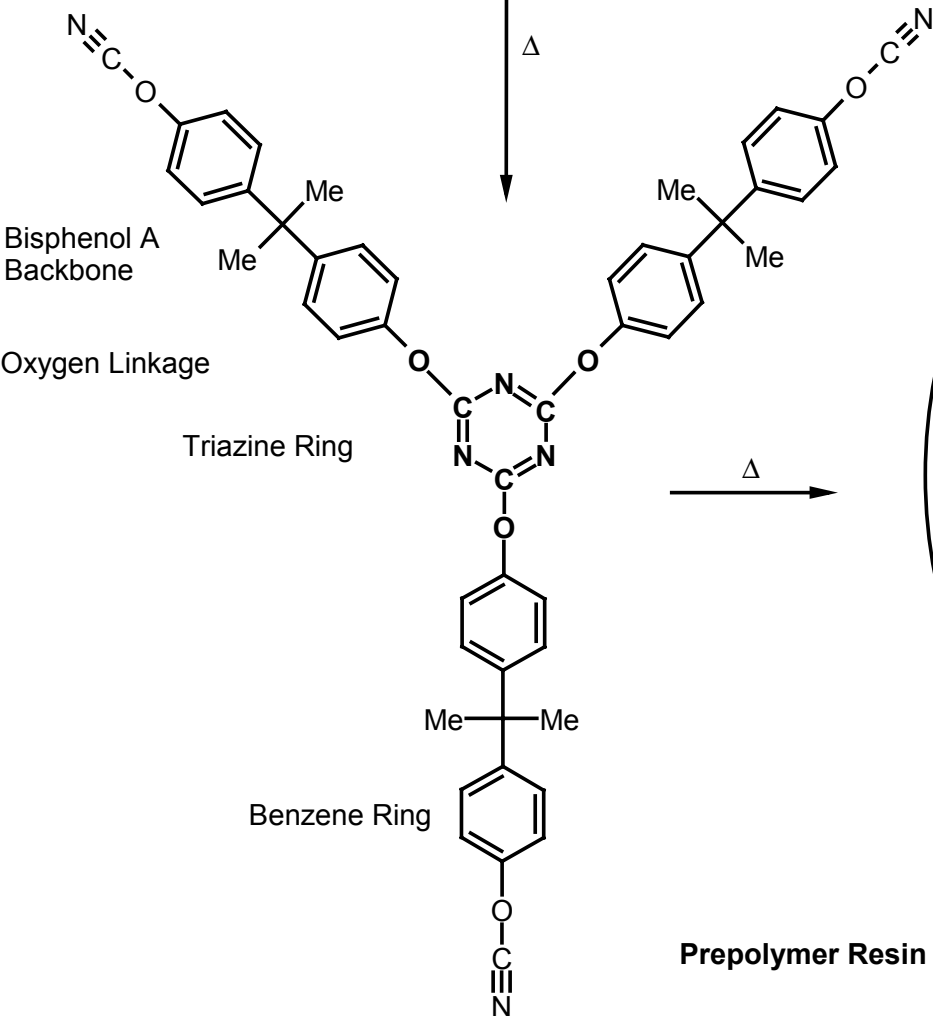
Reactions of Cyanate Esters

- **Polymerization**
(with other cyanate ester groups)
- **Copolymerization**
(with other cyanat ester groups and e.g. epoxides)
- **Addition of active Hydrogen containing compounds**
(Water, Alcohols, Amines; undesirable side reactions)

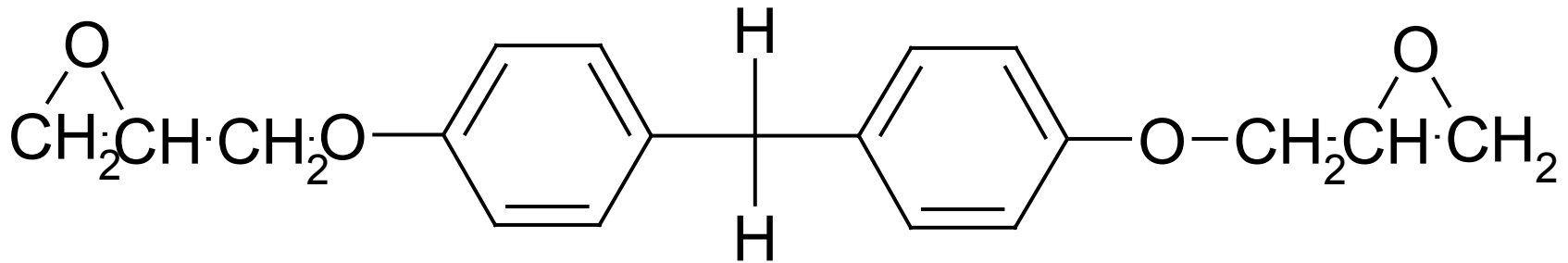
Dicyanate Monomer



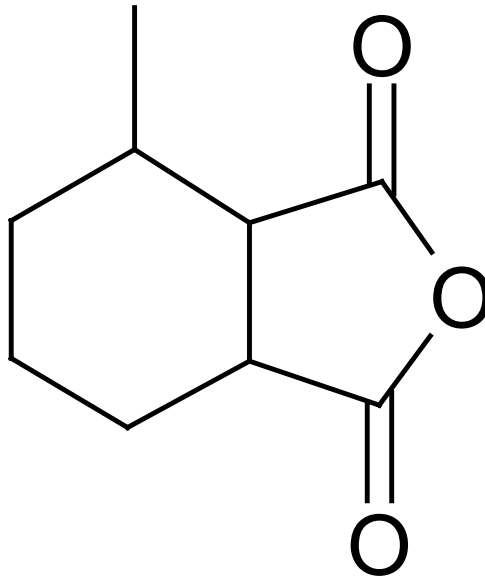
Cyanate esters Polymerization/Cyclotrimerization



Anhydride Curing



+



Bisphenol-F-DGE

MHHPA

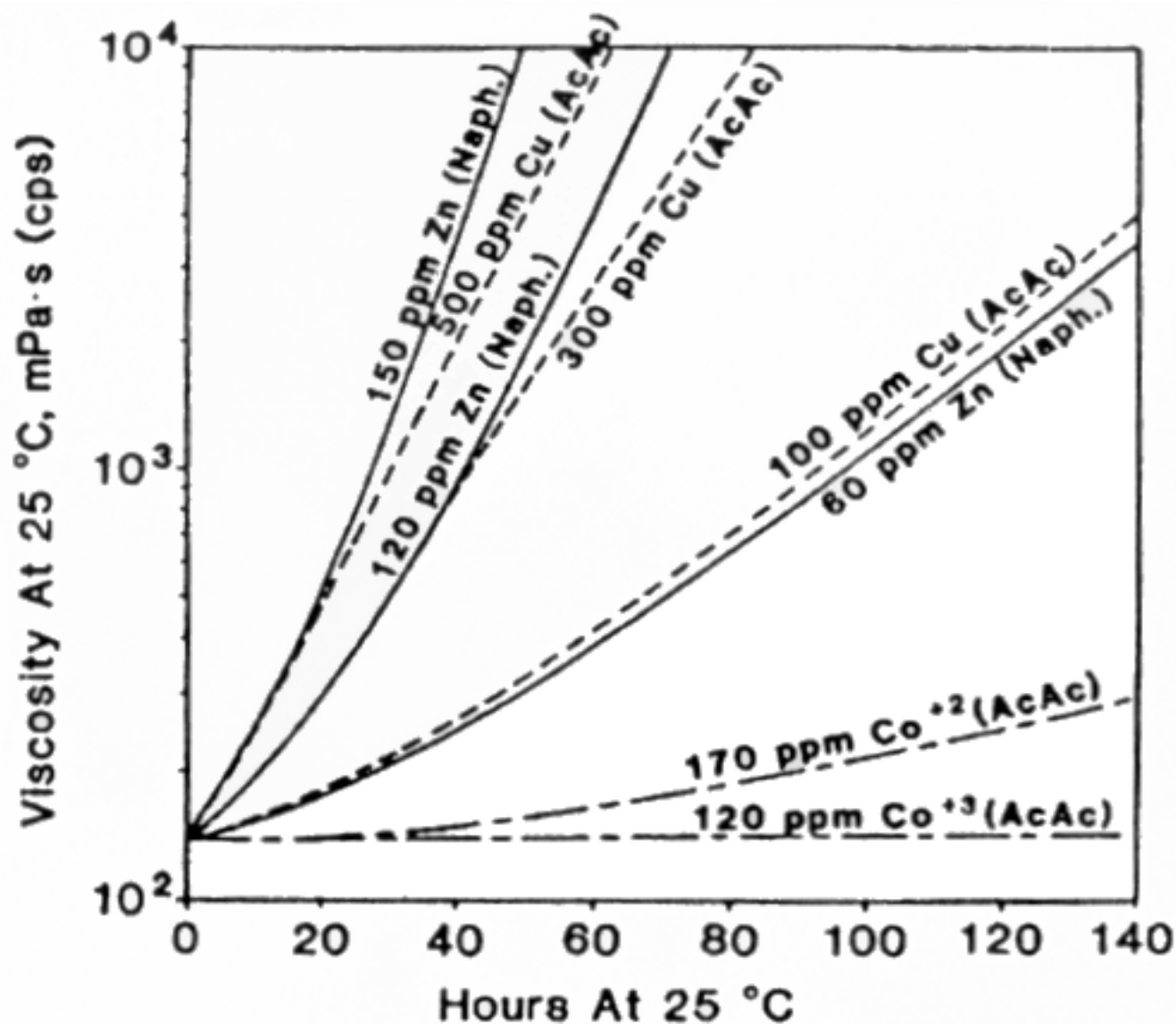
Polymerization of Cyanate Esters

- Pot life / speed of reaction strongly depends on catalyst type / concentration
- Catalysts must be added as homogeneous (filtered) solution to avoid any local high catalyst concentrations that could lead to uncontrollable reactions
- Polymerization is a highly exothermic reaction. Safety precautions!

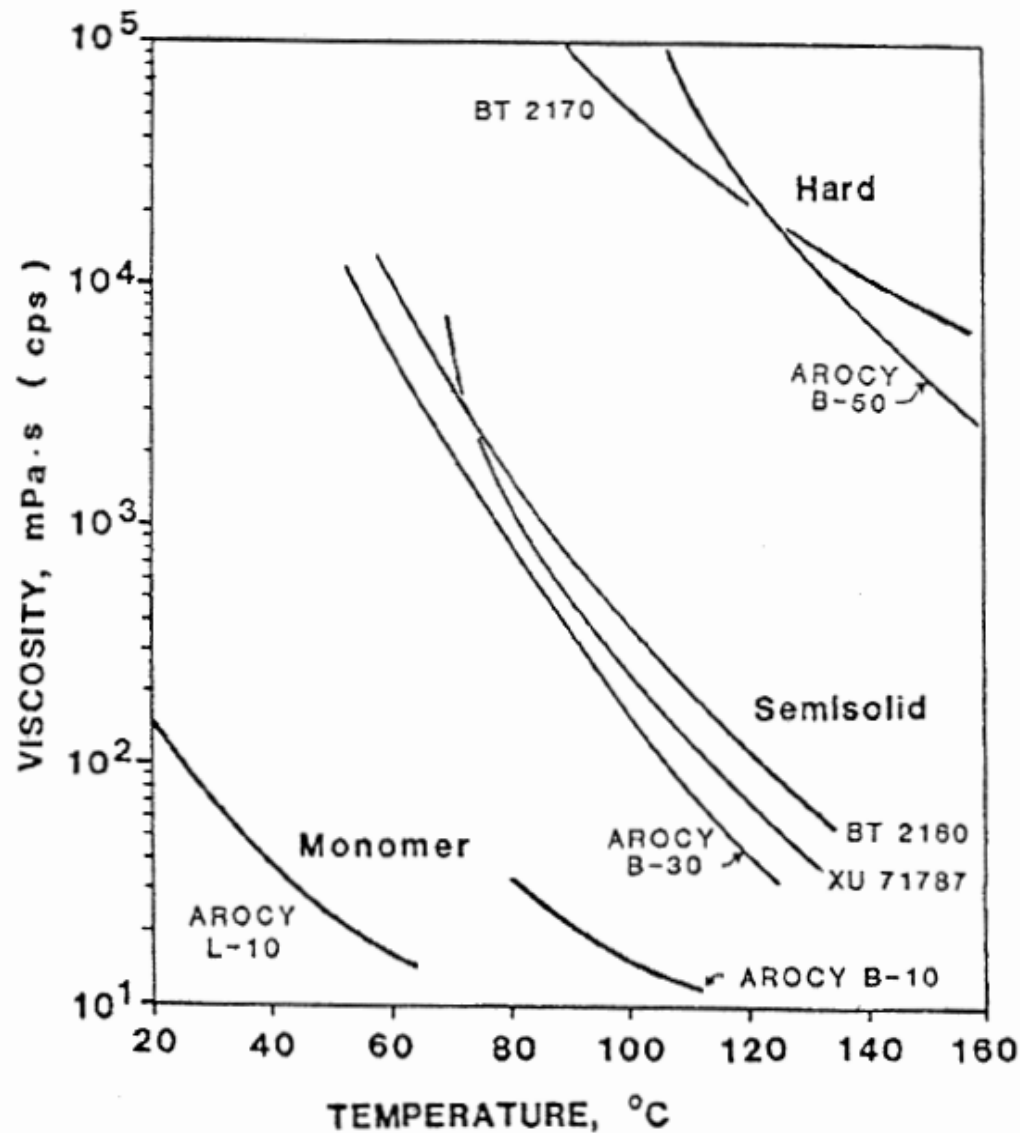
Cyanate Esters Polymerization Catalysts

- Metal catalysts (typical concentrations 20-300 ppm)
- Co, Zn, Mn, Cu ...
- Soluble organic salts/complexes are used e.g. acetylacetonates, octoates, naphthenates
- Solutions in liquid alkyl phenols

Reactivity of Cyanate esters

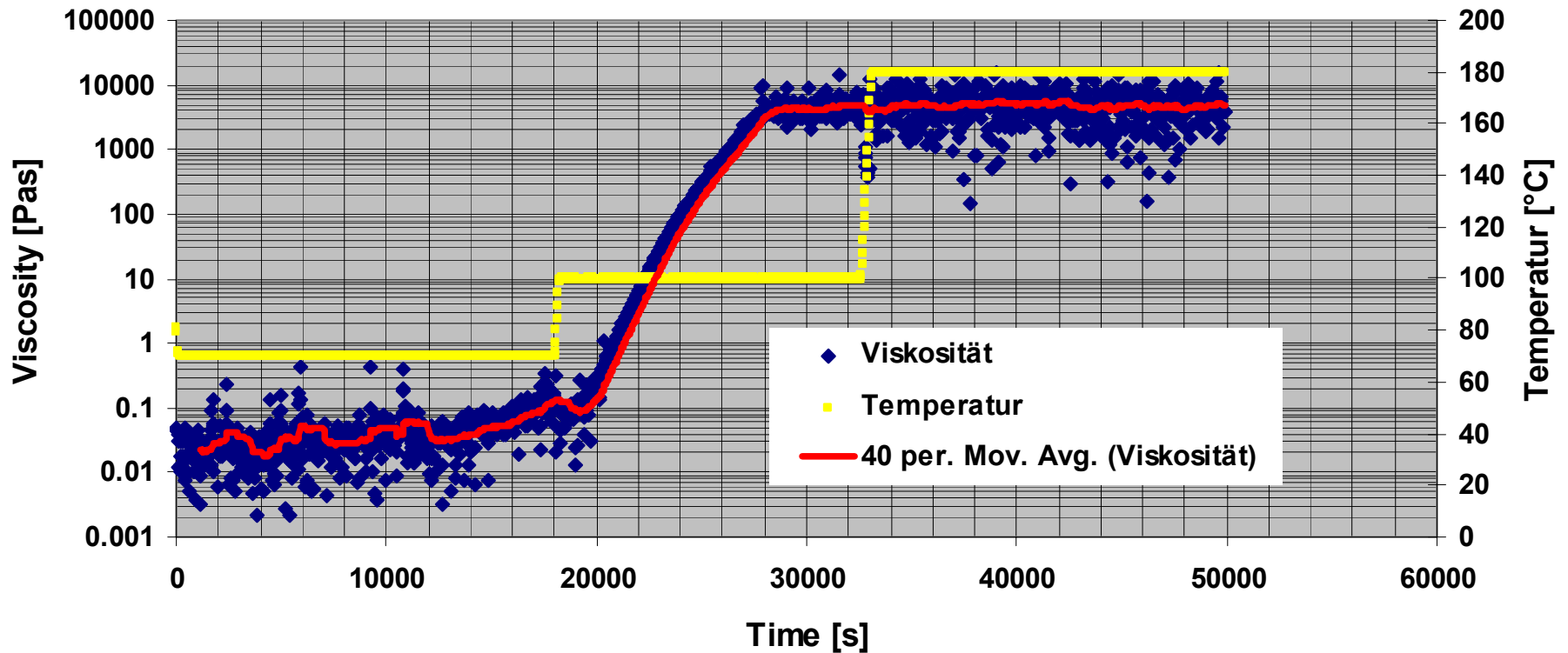


Viscosity of Cyanate esters



Processing of Cyanate esters

**Viscosity of AroCy L10 Versus Time
Catalyzed by 412 ppm Manganacetylacetonate**



AroCy[®] L-10

Typical processing parameters

- Melt AroCy L-10 49-54 °C
- Cool down to 25°-30 °C
- Mix with catalyst Safety!
- Heat to impregnation temp. Safety!
- Degassing ca. 8 mbar
- Potlife (Mn cat.see plot) >3h@70°C
- Gelation 3h@100°C
- Curing 5h@177°C

Cyanate esters: Exothermal reaction

- 100 KJoule/gram equivalent heat release on polymerization (similar to Epoxy ring opening)
- Uncontrolled adiabatic reaction could lead to temperature above 400 °C
- Safety precautions are a must

Cyanate Esters: Safety precautions

- No local overheating / only liquid heating media
- No solid catalyst / only filtered solutions
- No overcatalyzing
- No heating of catalyzed formulations above 30°C / only with cont. stirring and temp. control
- No catalytic contaminants (metal salts, water, acids) / sealed containers, dry storage
- Installations with cooling jackets/coils, quench tanks
- Excess quantities can be absorbed by porous heat sink material

Cyanate Esters: Why/where are they actually used ?

Key properties

- High glass transition temperature (180-280°C)
- Excellent dielectric properties
- Good adhesion to metals, ceramics..
- Conventional processing

Applications

- High performance circuit boards, adhesives, radar signal processing, military aircraft

Commercial Status AroCy[®] L-10

Regular commercial (make to order)

HUNTSMAN product

TSCA / EINECS Registered

Standard package is 40 lb pail

6 months forecast for ton quantities